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DOMESTIC PREPAREDNESS PROGRAM EVALUATION OF THE IMS2000™ (BRUKER DALTONICS GmbH ION MOBILITY SPECTROMETER 2000) AGAINST CHEMICAL WARFARE AGENTS SUMMARY REPORT

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This report characterizes the chemical warfare (CW) agent detection characteristics of the commercially available IMS2000^{TM}. This instrument is an ion mobility spectrometer, designed for detection and monitoring of chemical warfare agents and industrial toxins. The instrument was tested against HD, GB, and GA vapor under various conditions. . This report provides the emergency responders concerned with CW agent detection and verification an overview of the capabilities of the IMS2000^{TM}.

14. SUBJECT TERMS

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GB Ion Mobility Spectrometer (IMS)
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PREFACE

The work described herein was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. This work was started in March 2002 and was completed in October 2002.

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EVALUATION OF THE IMS2000™
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AGAINST CHEMICAL WARFARE AGENTS
SUMMARY REPORT

1. INTRODUCTION

The Department of Defense (DOD) formed the Domestic Preparedness (DP) Program in 1996 in response to Public Law 104-201. One of the objectives is to enhance federal, state, and local capabilities to respond to Nuclear, Biological and Chemical (NBC) terrorism incidents. Emergency responders who encounter either a contaminated or a potentially contaminated area must survey the area for the presence of either toxic or explosive vapors. Presently, the vapor detectors commonly used are not designed to detect and identify chemical warfare (CW) agents. Little data are available concerning the ability of these commonly used, commercially available detection devices to detect CW agents. Under the DP Expert Assistance (Test Equipment) Program, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to address this need. The Applied Test Team (ATT), Aberdeen Proving Ground, Maryland, performed the testing. ATT is tasked with providing the necessary information to aid authorities in the selection of detection equipment applicable to their needs.

Reports of the instrument evaluations are posted in the Homeland Defense website (http://hld.sbccom.army.mil/) for public access. Instruments evaluated and reported since 1998 include:

- MiniRAE plus from RAE Systems, Incorporated (Sunnyvale, CA)
- Passport II Organic Vapor Monitor from Mine Safety Appliance Company (Pittsburgh, PA)
- PI-101 Trace Gas Analyzer from HNU Systems, Incorporated (Newton, MA)
- TVA 1000B Toxic Vapor Analyzer (PID and FID) from Foxboro Company (Foxboro, MA).
- Draeger Colorimetric Tubes (Thioether and Phosphoric Acid Ester) from Draeger Safety, Incorporated (Pittsburgh, PA)
- Photovac MicroFID detector from Perkin-Elmer Corporation (Wellesley, MA)
- MIRAN SapphIRe Air Analyzer from Foxboro Company (Foxboro, MA)
- MSA Colorimetric Tubes (HD and Phosphoric Acid Ester) from Mine Safety Appliances Company (Pittsburgh, PA)
- M90-D1-C Chemical Warfare Detector from Environics OY, Finland
- APD2000 Detectors from Environmental Technologies Group, Incorporated (Baltimore, MD)
- SAW MiniCAD mkII from Microsensor Systems, Incorporated (Apopka, FL)
- UC AP2C Monitor from Proengin Incorporated, France
- ppbRAE Photo-Ionization Detector from RAE Systems, Incorporated (Sunnyvale, CA)

- SABRE2000 detector from Barringer Technologies, Incorporated (Warren, NJ)
- CAM (Type L) from Graseby Dynamics Ltd., United Kingdom
- VaporTracer System from Ion Track Instruments, Incorporated (Wilmington, MA)
- HAZMATCAD from Microsensor Systems, a Sawtek Company (Apopka, FL)
- GC-MS/FPD with Dynatherm System from Agilent (Columbia, MD)
- Scentoscreen GC from Sentex Systems, Incorporated (Fairfield, NJ)

In 2002, the evaluation of instruments continued using test items that were loaned to the DP program by their respective manufacturers. Viable candidate instruments were required to pass a pre-screening test. In exchange, the instruments were evaluated under the DP protocol and the manufacturers were permitted to take data during the evaluations. Instruments evaluated included:

- RAID-M from Bruker Saxonia Analytik GmbH (Leipzig, Germany)
- IMS2000 from Bruker Daltonics GmbH (Switzerland)
- Travel*IR* from SensIR Technologies (Danbury, CT)

Each of these evaluations will be reported separately. This report pertains to the evaluation of the IMS2000^{TM} (Ion Mobility Spectrometer 2000) from Bruker Daltonics GmbH. A glossary of acronyms is provided in the Appendix.

2. OBJECTIVE

The objective of this report is to assess the capability and general characteristics of the IMS2000^{TM} to detect CW agent vapors. The intent is to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of the instrument.

3. SCOPE

This DP evaluation is an attempt to characterize the CW agent vapor detection capability of the IMS2000^{TM}. The agents used were tabun (GA), sarin (GB), and mustard (HD). These were chosen as representative CW agents because they are believed to be the most likely threats. Test procedures follow the established DP Detector Test and Evaluation Protocol described in the Phase 1 Test Report[1]. The test concept was as follows:

a. Determine the Minimum Detectable Level (MDL) where repeatable detection readings are achieved for each selected CW agent. The current military Joint Services Operational Requirements (JSOR)[2] served as a guide for detection sensitivity objectives.

b. Investigate the effects of humidity and temperature on instrument performance.

c. Observe the effects of potential interfering substances upon instrument performance both in the laboratory and in the field.

4. EQUIPMENT AND TEST PROCEDURES

4.1 Instrument Description

Bruker Daltonics GmbH (Switzerland) is the manufacturer of the IMS2000^{TM} ion mobility spectrometer tested. Three units were loaned to the DP Program for inclusion in the 2002 detector evaluations. According to the Operator's Handbook[3], the IMS2000^{TM} is a compact, hand-held sensor, capable of detecting the presence of vapor from chemical compounds, such as chemical warfare agents (CWA) and industrial toxins. The manufacturer states that the instrument is capable of continuous running and monitoring simultaneously in positive and negative ion modes for rapid detection and identification of all the major classes of CW agents. The ergonomic design of the IMS2000^{TM} provides for one-hand operation, with easily accessible controls and audible and visual warnings. It is designed to be usable even when wearing full individual protective equipment (IPE) (this capability was not addressed in this test). The instrument can be connected to a computer or bus interface and remotely operated if required.

The instrument operates on either an internal lithium manganese dioxide battery or connected to an external power supply system (30W military standard) that connects to an 85 to 265V AC outlet. Both battery and power source are provided in the assessory kit. The IMS2000^{TM} weighs 2.20kg without the battery pack and 2.65kg with the battery pack.

The IMS2000^{TM}operates by measuring the drift time of different ionized molecules within a drift tube working under atmospheric pressure (time of flight measurement). A micro-controller and on-board analytical software perform substance identification. The device uses a radioactive source (63Ni Beta radiator) within its sensor cell for the ionization process. A chemical dopant is required for the IMS that must be replenished when necessary. There are also three filters that need to be changed at appropriate intervals or when the instrument shows a warning message. They are the drying filter (250 hours of operation), back-flush filter (2600 hours of operation), and dust filter (on condition). A servicing tool is provided with the instrument.

The dimensions of the IMS2000^{TM} are 360mm by 110mm with a height of 145mm. Figure 1 shows a top view of the IMS2000^{TM}. The instrument is switched on by pressing the left-hand switch by the liquid crystal display (LCD) window. By pressing the right-hand and left-hand switches, the various screens are accessed and indicated on the LCD thru easy symbology that are explained fully in the Operator's Handbook. These switches are used to step through menus of options and operate the instrument. The unit starts up in the standard detection mode that is the normal operating mode. A high sensitivity mode can be selected for monitoring low toxic levels. The high sensitivity mode differs from the standard mode only in the hazard level bar display (over a wider bar range). Standard mode shows a linear hazard level bar graph response on the LCD along with a visual warning indicator light. The hazard level bars indicate the detection response by an increasing number of lighted bars beside the response ID on the LCD according to the detection. Up to five bars can be lit according to the degree of "hazard" detected. An audible alarm sounds when two or more bars are indicated on the hazard level bar display.

Figure 1. Bruker Daltonics GmbH Ion Mobility Spectrometer 2000

4.2 Calibration

Operating procedures were followed according to the operator's handbook. No daily instrument calibration, except for a confidence check, is required by the manufacturer to place the IMS2000™ into operation. The instrument is switched on and allowed to reach its operating temperature. In the warm-up mode the state of readiness is indicated in the multi-function indicator bar of the display. When it has reached its operating temperature, the display automatically indicates PURGE. The IMS2000™ switches automatically and continuously between nerve agent detection (+ or G) and blister agent detection (- or H) every two seconds. When purging is complete (both G and H) the display automatically switches to the SAMPLE display. The inlet nozzle of the instrument has two interchangeable caps, a protection cap and a sampling cap. The protective cap is over the sampling inlet nozzle when switched on and is replaced by the sampling cap for sampling per operating instructions. Following this, the instrument is ready for a confidence test using the confidence tester (simulant) provided with the instrument. The confidence tester is a double-ended unit that contains Diproplylene glycolmonomethylether (DPM) for simulation of nerve agents in one end labeled 'G' and Methyl Salicylate (MS) for simulation of blood and blister agents in the other end labeled 'H'.

The confidence tester is removed from the transport container and the "G" simulant end is opened and held close to the sampling cap inlet for about a second, then the tester is removed and closed. The IMS2000™ should react within 10 seconds and indicate on the "G" mode hazard-level indicator display. The sampling cap is then removed and the protection cap is put

in its place. When the instrument has purged and is again ready for sampling, the process is repeated using the "H" simulant.

4.3 Agent Vapor Challenge

The agent challenges were conducted using the Multi-Purpose Chemical Agent Vapor Generation System[4] using Chemical Agent Standard Analytical Reference Material (CASARM) grade or the highest purity CW agents available. Agent challenge followed successful instrument warm up and confidence check. The vapor generator system permits testing of the instrument with humidity and temperature-conditioned air without agent vapor before challenging it with similarly conditioned air containing the CW agent vapor. This is to assure that the background air does not interfere with the instrument.

The IMS2000™ sampling inlet was placed under the cup-like sampling port of the vapor generator and exposed to the conditioned air to establish a stable background before agent challenges. Agent challenge begins when the solenoids of the vapor generation system are energized to switch the air streams from conditioned air only to similarly conditioned air containing the agent. The instrument immediately begins to sample. The time that the detector was exposed to the agent vapor until it first alarmed was recorded as the response time. The time required for the instrument to stop alarming after the sample run was noted as the recovery time.

Three units, randomly labeled A, B, and C, were originally delivered for testing. Units A and B were used to begin the testing with Unit C remaining as a backup unit. After 3 months of testing, Unit B failed to start for unknown reasons and Unit C was placed into the test program for completion of data collection. The instruments were tested with the CW agents GA, GB, and HD at several concentration levels at ambient temperatures (20- 27 ^{o}C) and 50% relative humidity (RH) to determine the MDL for each agent. The instruments were then tested at the determined MDL concentrations, ambient temperatures, and both <10 % and >90 %RH conditions to observe potential humidity effects. Each unit was tested three times under each condition. The effects of low temperature were assessed by testing at –30°C for GA, - 34°C for GB*, and 0°C for HD. Although HD freezes at approximately +15°C, the calculated HD volatility of 92 mg/m^3 at 0°C easily produces a vapor concentration higher than the 2 mg/m^3 Joint Service Operational Requirement (JSOR) detection criteria allowing the instrument to be evaluated against HD down to 0°C.

The effects of high temperatures were assessed by testing at +45°C for both GA and GB, and +52°C for HD. Problems testing GA and GB with the IMS2000™ units at +52°C led to the manufacturer recommended reducing chamber temperature until the units worked properly which turned out to be +45°C.

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* The temperature difference resulted from problems with the temperature conditioning facility.

4.4 Agent Vapor Quantification

The generated agent vapor concentrations were analyzed independently and are reported in the data tables. The vapor concentration was quantified by utilizing the manual sample collection methodology[5] using the Miniature Continuous Air Monitoring System (MINICAMS®) manufactured by O. I. Analytical, Inc. (Birmingham, AL). The MINICAMS® is equipped with a flame photometric detector (FPD), and was operated in either phosphorus mode for the GA and GB agents or sulfur mode for HD.

The MINICAMS® normally monitors air by collection through sample lines and subsequently adsorbing the CW agent onto the solid sorbent contained in a glass tube referred to as the pre-concentrator tube (PCT). The PCT is located after the MINICAMS® inlet. The concentrated sample is periodically heat desorbed into a gas chromatographic capillary column for subsequent separation, identification, and quantification. For manual sample collection, the PCT was removed from the MINICAMS® during the sampling cycle and connected to a measured suction source to draw the vapor sample from the agent generator. The PCT was then re-inserted into the MINICAMS® for analysis. This "manual sample collection" methodology eliminated potential loss of sample along the sampling lines and the inlet assembly when the MINICAMS® was used as an analytical instrument. The calibration of the MINICAMS® was performed daily using the appropriate standards for the agent of interest. The measured mass equivalent (derived from the MINICAMS chromatogram) divided by the total volume (flow rate multiplied by time) of the vapor sample drawn through the PCT produced the sample concentration that converts into milligrams/cubic meter.

4.5 Field Interference Tests

The instruments were tested outdoors in the presence of common potential interferents such as the vapors from gasoline, diesel fuel, jet propulsion fuel (JP8), kerosene, Aqueous Film Forming Foam (AFFF, used for fire fighting) and household chlorine bleach. Vapor from a 10% calcium hypochlorite solution (HTH slurry, a chlorinating decontaminant for CW agents), engine exhausts, burning fuels, and other burning materials were also tested. The objective was to assess the ability of the instruments to withstand outdoor environments and to resist false alarm responses when exposed to the selected substances. In these tests, no CW agent was present.

The field tests were conducted outdoors at M-Field of the Edgewood Area, Aberdeen Proving Ground, in September 2002. These experiments involved open containers, truck engines, and fires producing smoke plumes, which were sampled by the detectors at various distances downwind. The IMS2000™ units were exposed to either the smoke or fume test plumes to achieve moderate concentrations (e.g. 1-4 ft for vapor fumes and 8-15 ft for smokes).

Confidence checks were performed on each unit at the beginning of each testing day. The two units were exposed to each interferent for approximately 5 minutes for three trials when possible. The units were tested in the standard sample mode. Testing continued with the next challenge after the instruments were thoroughly recovered from prior exposure indicated by "Sample" and one or less indicator bars on the LCD.

4.6 Laboratory Interference Tests

The laboratory interference tests were designed to assess the effect on the detectors of vapor exposure from potential interfering substances. The substances were chosen based on the likelihood of their presence during an emergency response by first responders. Additionally, the laboratory interference tests were conducted to assess the CW agent detection capability in the presence of these interferent vapors. Only HD and one nerve agent, GB, were tested in the laboratory interference testing due to time constraints.

The IMS2000™ units were tested against 1% of the headspace concentrations of gasoline, JP8, diesel fuel, household chlorine bleach, floor wax, AFFF, Spray 9™ household cleaner, Windex™ window cleaner, toluene, antifreeze and vinegar vapors. They were also tested against 25 ppm NH_3 (ammonia). If the detector false alarmed at 1% concentration, it was tested at the 0.1% concentration of the substance.

To generate the respective vapor concentrations, a dry air stream carried the headspace vapor of the substance by sweeping it over the liquid in a tube or through the liquid in a bubbler to prepare the interferent gas mixture. For example, 30 milliliters/minute (mL/min) or three mL/min of this vapor saturated air diluted to three liters/minute (L/min) with the conditioned air at ambient temperatures (22-24°C) and 50-52% RH produce either the 1% or 0.1% concentration of interferent test mixture, respectively. The 25 parts per million (ppm) ammonia was derived by proper dilution of a stream from an analyzed 1% NH_3 vapor (10,000 ppm) compressed gas cylinder diluted with the appropriate amount of the conditioned air.

For the tests that included CW agent, the interferent test gas mixture was prepared similarly. The resultant stream of three L/min of CW agent vapor was used as a dilution stream to blend in with the appropriate 30 or three mL/min of the substance vapor flow to obtain the desired 1% or 0.1% mixture of the substance vapor in the presence of CW agent concentration. The two units were tested three times with each combination of agent plus interferent.

5. RESULTS AND DISCUSSION

5.1 Minimum Detectable Levels (MDL)

The MDL, with corresponding response times for the IMS2000™ units tested, are shown in Table 1 for each agent at the ambient temperatures and 50% RH. The MDL values represent the lowest CW agent concentration where identification of the CW agents occurred consistently for three trials. Concentration units are shown in both milligrams per cubic meter (mg/m^3) and ppm. For comparison, the current military JSOR requirements for CW agent sensitivity for point detection alarms, the U.S. Army's established values for Immediate Danger to Life or Health (IDLH), and the AEL, are also listed in Table 1. Army Regulation (AR) 385-61[5] is the source for the IDLH and AEL values for GA and GB, and the AEL value for HD. The AR 385-61 does not establish an IDLH for HD due to concerns over carcinogenicity.

In standard mode, the IMS2000™ units detected HD at 0.14 mg/m^3 in approximately two minutes or less, which is an order of magnitude better (lower) than the JSOR level. The units detected GA at 0.016 mg/m^3 in less than 79 seconds and GB at 0.03 mg/m^3 in less than two

minutes, which are both better than the published JSOR level. The units detected HD and GB in less than seven seconds, and GA in less than 11 seconds at the approximate published JSOR level. Greater sensitivity was noted when tested in the high sensitivity mode (HIGH SENSE), as shown in Table 2. The units were unable to detect GA, GB, or HD at the AEL levels.

Table 1. Minimum Detectable Level (MDL) and Range of Response Times at Ambient Temperatures and 50% RH for the IMS2000™

AGENT	Concentration in milligrams per cubic meter, mg/m^3, with parts per million values in parentheses (ppm), and Response Times				
	IMS2000™ MDL Standard	IMS2000™ MDL High S	JSOR*	IDLH**	AEL***
HD	0.14 (0.02) in 52-141sec	0.09 (0.01) in 14-63sec	2.0 (0.300) in 120 sec	N/A	0.003 (0.0005) up to 8 hr
GA	0.016 (0.002) in 42-79sec	0.007 (0.001) in 31-73sec	0.1 (0.015) in 30 sec	0.2 (0.03) up to 30 min	0.0001 (0.000015) up to 8 hr
GB	0.03 (0.005) in 39-120sec	0.017 (0.003) in 38-134sec	0.1 (0.017) in 30 sec	0.2 (0.03) up to 30 min	0.0001 (0.000017) up to 8 hr

* Joint Service Operational Requirements for detectors.

** Immediate Danger to Life or Health values from the unclassified Army Regulation (AR) 385-61, Feb 1997, to determine level of CW protection. Personnel must wear either the full ensemble with SCBA for operations or full-face respirator for escape.

***Airborne Exposure Limit values from AR 385-61 to determine masking requirements. Personnel can operate for up to 8 hr unmasked.

Table 2. IMS2000™ Responses in High Sensitivity Mode

Agent	Average Conditions		Challenge Concentration		Response Time, seconds
	Temperature °C	RH %	mg/m³	ppm	
HD	20-21	48-51	0.0100	0.0021	No Alarm
			0.0260	0.0039	No Alarm (1 Bar)
			0.0900	0.0132	14-63
GA	21-22	49-50	0.0020	0.0003	No Alarm (1 Bar, 1 unit only)
			0.0030	0.0004	No Alarm (1 Bar)
			0.0070	0.0010	31-73
GB	20-22	50	0.0050	0.0009	No Alarm
			0.0060	0.0010	No Alarm (1 Bar)
			0.0170	0.0029	38-134

5.2 Temperature and Humidity Effects

Tables 3, 4, and 5 show the results of the IMS2000™ evaluation under various test conditions for agents HD, GA, and GB, respectively. All temperature and humidity effects testing was completed in standard operating mode. Humidity effects tests were conducted at ambient temperatures and approximately <10%, 50%, and >90% RH. The IMS2000™ manual states an operational temperature range of –32°C to +55°C for their instrument. An attempt was made to test the instruments at temperature extremes within the operational range.

The concentrations used to determine the temperature and humidity effects were based on the previously determined MDLs. Positive detection response is defined as three consistent responses in three independent trials for the agent, for both IMS2000™ units at the temperature and RH specified. The corresponding range of response times for the two units is given in each table.

Table 3 shows that the IMS2000^{TM} demonstrated HD detection at previously determined MDLs at ambient temperature and lower RH levels (<60%) and in the cold temperature tests. It appears that high temperature and high RH at ambient had adverse effects on HD detection, requiring higher concentrations to cause an alarm. Some difficulty was noted at high temperature testing of HD, with one unit's sensitivity being ten times that of the other. However, lower RH at ambient temperature had a beneficial effect, lowering the MDL. Recovery times for HD exposure were <30 seconds, except at high concentrations. At high concentrations, the units required up to 178 seconds for recovery.

Table 3. IMS2000™ Responses to HD Vapor Concentrations at Various Conditions

Average Conditions		HD Challenge Concentration		Response Time, seconds
Temperature, °C	RH, %	mg/m^3	ppm	
20-21	0-1	0.06	0.01	No Alarm (1 Bar)
		0.07	0.01	54-110
		0.23	0.03	11-60
		50.00	7.61	3-9
21-25	49-51	0.08	0.01	No Alarm (1 Bar)
		0.14	0.02	52-141
		0.25	0.04	14-97
		2.24	0.34	4-7
21	89	0.15	0.02	No Alarm (1 Bar)
		0.26	0.04	33-92
0-1	0	0.07	0.01	No Alarm (1 Bar)
		0.10	0.01	36-42 (1 unit only)
		0.14	0.02	9-29
52	33-49	0.09	0.02	No Alarm
		0.19	0.03	12-13 (1 unit only)
		0.33	0.06	6-12 (1 unit only)
		1.97	0.33	4-12
		49.20	8.25	3-8

Table 4 shows that the IMS2000^{TM} demonstrated GA detection at previously determined MDLs at ambient temperatures with lower and higher RH producing no adverse effects. It appears that high and low temperatures had adverse effects on GA detection, requiring higher concentrations to cause an alarm. Also, some difficulty was noted at low temperature testing of GA, with one unit's sensitivity being three times that of the other. When detection occurred, recovery times for GA exposure were <40 seconds, except at high concentrations. At high concentrations, the units required up to 393 seconds for recovery.

Table 4. IMS2000™ Responses to GA Vapor Concentrations at Various Conditions

Average Conditions		GA Challenge Concentration		Response Time, seconds
Temperature, °C	RH, %	mg/m³	ppm	
21	0	0.015	0.002	40-115
20-21	48-52	0.004	0.001	No Alarm
		0.007	0.001	No Alarm (1 Bar)
		0.016	0.002	42-79
		0.118	0.018	7-11
		1.080	0.167	4-8
21	91	0.016	0.002	19-87
-30	6	0.048	0.006	No Alarm
		0.071	0.009	88 (GB 1 unit only)
		0.150	0.019	70-81 (GB 1 unit only)
		0.202	0.025	48-120 (GB & GA)
45	37	0.018	0.003	No Alarm (1 Bar)
		0.038	0.006	12-52

Table 5 shows that the IMS2000™ demonstrated GB detection close to previously determined MDLs at both temperature and RH extremes. Recovery times for GB exposure were <20 seconds, except at high concentrations. At high concentrations, the units required up to 35 seconds for recovery. It appears that high and low temperatures had very slight adverse effects on GB detection, requiring slightly higher concentrations to cause an alarm. Again, some difficulty was noted at high temperature testing of GB, with one unit not operating, but then operating when temperature was reduced by 7 degrees C. Thus, high temperature testing was conducted at 45°C.

Table 5. IMS2000™ Responses to GB Vapor Concentrations at Various Conditions

Average Conditions		GB Challenge Concentration		Response Time, seconds
Temperature, °C	RH, %	mg/m³	ppm	
21	0-1	0.022	0.004	No Alarm (1 Bar)
		0.036	0.006	40-108
		0.056	0.010	11-21
20-21	50-54	0.011	0.002	No Alarm
		0.022	0.004	No Alarm (1 Bar)
		0.030	0.005	43-120
		0.115	0.020	7-11
		0.970	0.167	3-7
21	96	0.028	0.005	41-55 (1 unit only)
		0.038	0.007	25-89
		0.047	0.008	10-79
-34	2	0.036	0.005	No Alarm (1 Bar)
		0.045	0.006	66-102
45	38	0.031	0.006	9-89
52	35-36	0.032	0.006	No Alarm (1 Bar)
		0.050	0.010	12-43 (1 unit only)

5.3 Field Interference

The results of the field test interferent exposures are presented in Table 6 as the number of alarms per number of trials. A false positive response indicates that the instrument showed an agent detection response in the absence of CW agent when challenged with potential interferent substances. Field test conditions were 20-27°C (68–81°F) and 33-77% RH, with gentle winds. Confidence checks were successfully performed on both units at the start of each day.

Each unit was tested three times against the listed interferents, with a five minute exposure time, when possible. Fewer tests of the doused wood fire and the burning tire smoke

were conducted. As shown, the units were tested only once against the doused fire and against the doused burning tire due to excessive residual effects.

Because the smokes appeared to coat the intake filters of the units, the filters were changed after each smoke test. The overall alarm rates across all tests were 17 of 53 trials (32%) for unit A and 17 of 54 trials (31%) for unit C.

Neither unit alarmed when exposed to bleach vapor, revving diesel engine exhaust, diesel fuel vapor, revving gasoline engine exhaust, idling gasoline engine exhaust, gasoline vapor, HTH 10% vapor, JP8 vapor, kerosene vapor, and burning kerosene. Both units alarmed “HD” to burning cardboard. Only unit C alarmed “HD” to burning cloth. Both units alarmed “GA” to AFFF vapor and doused burning tire. Both units alarmed “GB” to burning cardboard. Only unit A alarmed “GB” to burning diesel fuel, and only on one trial. Both units alarmed “L” to burning cardboard. Only unit A alarmed “L” to burning cloth and burning gasoline. Both units alarmed “VX” to burning cardboard, burning cloth, burning gasoline, burning JP8, burning tire, doused burning tire, burning wood, and doused burning wood. Post field test responses against CW agent vapor challenges showed the IMS2000™ units to have no adverse residual effects from the field tests. Response characteristics were similar to the pre-field test results.

Table 6. IMS2000™ Field Interference Testing Summary

INTERFERENT	Alarms/Trials, False Response ID	
	Unit A	Unit C
AFFF (6%) Vapor	2/3 GA	1/3 GA
Clorox (6% Bleach) Vapor	0/3	0/3
Burning Cardboard	2/2 GB, HD, L, VX	3/3 GB, HD, L, VX
Burning Cloth	1/1 L, VX	1/1 HD, VX
Diesel Revving - exhaust	0/3	0/3
Diesel Vapor	0/3	0/3
Burning Diesel	1/3 GB	0/3
Gas Idling - exhaust	0/3	0/3
Gas Revving - exhaust	0/3	0/3
Gasoline Vapor	0/3	0/3
Burning Gasoline	1/3 L, VX	1/3 VX
HTH (10% calcium hypochlorite) Vapor	0/3	0/3
JP8 Vapor	0/3	0/3
Burning JP8	2/3 VX	3/3 GS*, VX
Kerosene Vapor	0/3	0/3
Burning Kerosene	0/3	0/3
Burning Tire	3/3 VX	3/3 VX
Doused Burning Tire	1/1 GA, VX	1/1 GA, VX
Burning Wood	3/3 VX	3/3 VX
Doused Burning Wood	1/1 VX	1/1 HD, VX
TOTAL Alarms/Trials	17/53	17/54

*GS is a code for CW (nerve) agent simulant per the IMS2000™ manual.

5.4 Laboratory Interference Tests

The laboratory interference tests were conducted at ambient temperatures (22-24^{o}C) and approximately 50% RH. The IMS2000^{TM} units were tested against both HD and GB using concentrations above the previously determined MDL. The instruments were exposed to each interferent at 1% of saturation. If the units showed no response to an interferent then the units were exposed to the respective CW agent in the presence of the interferent. If 1% of saturation interfered with the instrument, the interferent was reduced to 0.1% of saturation. Each test was repeated three times.

Table 7 presents the results of exposing the IMS2000^{TM} instruments to several potential interferents both in the presence of and without HD agent. The HD bar responses with corresponding response times are given for both agent-only detection response and agent-plus-interferent detection response.

The IMS2000^{TM} units produced a false positive alarm to the following interferent substances at 1% of saturation: AFFF, floor wax, gasoline, Spray 9™ and Windex™. The 1% vinegar vapor prevented the units from detecting HD even though no false was seen with vinegar only. However, the units correctly responded to HD after the vinegar was reduced to the 0.1% saturation level. The units showed a false positive alarm at 0.1% of saturation to Floor wax (Unit A only), Gasoline (Unit C only), Spray 9™ and Windex™. Except for vinegar, the HD responses with and without interferent were comparable as tested.

Table 7. IMS2000™ Responses to HD Vapor Concentrations With and Without Interferents at Ambient Temperatures and 50 %RH

Interferent			HD Challenge without interferent			HD Challenge Plus interferent	
Interferent	Response, Number of Bars and Agent ID	Response Time, (sec)	mg/m^3 (ppm)	Response, Number of Bars and Agent ID	Response Time, (sec)	Response, Number of Bars and Agent ID	Response Time, (sec)
1% AFFF	2-3 GA	89-258	Not tested due to interference				
0.1% AFFF	No Interference		2.1 (0.32)	4-5 HD	6-8	4-5 HD	5-8
25ppm Ammonia	No Interference		2.0 (0.31)	4-5 HD	5-8	4-5 HD	4-9
1% Antifreeze	No Interference		1.9 (0.29)	3-5 HD	4-7	2-4 HD	5-13
1% Bleach	No Interference		2.2 (0.34)	3-5 HD	4-9	5 HD	5-9
1% Diesel	No Interference		2.1 (0.32)	4-5 HD	4-9	2-5 HD	6-8
1% Floor Wax	2 GB/GS	11-48	Not tested due to interference				
0.1% Floor Wax	2 GB*	81-156	2.0 (0.31)	4-5 HD	5-9	4-5 HD	5-9
1% Gasoline	2-3 GA/GB	7-12	Not tested due to interference				
0.1% Gasoline	1-2 GA**	25-32	2.0 (0.31)	4-5 HD	5-8	4-5 HD	6-9
1% JP8	No Interference		1.9 (0.29)	3-5 HD	4-7	5 HD	5-9
1% Spray 9™	2-4 GB/VX	9-12	Not tested due to interference				
0.1% Spray 9™	2 GB/VX	32-73	Not tested due to interference				
1% Toluene	No Interference		1.9 (0.29)	4-5 HD	6-8	5 HD	4-8
1% Vinegar	No Interference		1.8 (0.28)	3-5 HD	7-9	No Response	No Response
0.1% Vinegar	No Interference		1.8 (0.28)	3-5 HD	6-7	2-5 HD	9-66
1% Windex™	2-4 GB/VX	6-9	Not tested due to interference				
0.1% Windex™	GB* VX**	78* 20**	Not tested due to interference				

*Unit A only
**Unit C only

Table 8 presents the results of exposing the IMS2000^{TM} instruments to several potential interferents both with and without GB agent. If the units showed no response to an interferent then the units were exposed to GB in the presence of the interferent. The range of GB responses with corresponding response times are given for both agent-only detection response and agent-plus-interferent detection response

The IMS2000^{TM} units showed a false positive alarm to the following interferent substances at 1% of saturation: AFFF, floor wax, gasoline, Spray 9™ and Windex™. The units also produced a false positive alarm to Spray 9™ and Windex™ at 0.1% of saturation. As seen in Table 8, Unit C showed unexplained false 2 bar VX response instead of the expected GB response in several tests against GB only and GB plus interferent tests.

Table 8. IMS2000™ Responses to GB Vapor Concentrations With and Without Interferents at Ambient Temperatures and 50 %RH

Interferent			GB Challenge Without Interferent			GB Challenge Plus Interferent	
Interferent	Response, Number of Bars and Agent ID	Response Time, (sec)	mg/m³ (ppm)	Response, Number of Bars and Agent ID	Response Time, (sec)	Response, Number of Bars and Agent ID	Response Time, (sec)
1% AFFF	2 GA	43-85	Not tested due to interference				
0.1% AFFF	No Interference		0.11 (0.019)	2 GB	6-9	2-3 GB	7-10
25ppm Ammonia	No Interference		0.10 (0.017)	2 GB	7-11	2 GB	8-10
1% Antifreeze	No Interference		0.12 (0.021)	2-3 GB	7-10	3 GB	6-10
1% Bleach	No Interference		0.10 (0.017)	2 GB* 2 VX**	7-21* 15-22**	2 GB* 2 VX**	10-25* 21-25**
1% Diesel	No Interference		0.10 (0.017)	2 GB* 2 VX**	6-22* 15-22**	2 GB* 2 VX**	10-25* 14-18**
1% Floor Wax	2 GB	12-13	Not tested due to interference				
0.1% Floor Wax	No Interference		0.10 (0.017)	2 GB	7-11	2-3 GB	8-9
1% Gasoline	2 GB	4-16	Not tested due to interference				
0.1% Gasoline	No Interference		0.12 (0.021)	2-3 GB	6-10	2-3 GB	8-9
1% JP8	No Interference		0.10 (0.017)	2 GB* 2 VX**	9-22* 21-22**	2 GB* No Response or GF**	8-9* 137-213**
0.1% JP8	No Interference		0.10 (0.017)	2 GB* 2 VX**	9-19* 17-19**	2 GB* 2 VX**	9-16* 15-16**
0.1% Spray 9™	2 GB	26-37	Not tested due to interference				
1% Toluene	No Interference		0.11 (0.019)	2-3 GB	6-9	2 GB	6-8
1% Vinegar	No Interference		0.10 (0.017)	2 GB* 2 VX**	9-19* 17-18**	2 GB* 2 VX**	9-20* 17-20**
0.1% Windex™	2-3 GB	21-63	Not tested due to interference				
*Unit A only **Unit C only							

6. CONCLUSIONS

Conclusions are based solely on the results observed during this testing. Aspects of the detectors other than those described were not investigated.

Civilian first responders and HAZMAT personnel use Immediate Danger to Life or Health (IDLH) values to determine levels of protection for selection of personal protective equipment during consequence management of an incident. The minimum detection limit (MDL) of the IMS2000™ was below the IDLH and the current Joint Service Operational Requirement (JSOR) for point sampling detectors for all agents tested at ambient conditions. Most responses occurred in less than two minutes. The instruments are sensitive and can detect CW agents quickly at ambient temperature. The IMS2000™ units were unable to detect HD, GA, or GB, at the much lower AEL concentrations.

Higher temperatures required higher than MDL concentrations for alarm response for all agents tested. Some difficulty was noted at high temperature testing of HD, with one unit's sensitivity being ten times that of the other. Again, some difficulty was noted at high temperature testing of GB, with one unit not operating, but then operating when temperature was reduced by 7 degrees C. Some difficulty was noted at low temperature testing of GA, with one unit's sensitivity being three times that of the other. Low temperature testing for GB needed slightly higher than MDL concentrations for response but for HD had no adverse effects. High and low RH had no effect on response for GA or GB. However, low RH improved the MDL for HD while high RH required a higher than MDL HD concentration for response. It is important to note that even with these difficulties, detection was near the IDLH and JSOR levels.

False alarms to tested field interference substances were observed in 17 of 53 trials (32%) for unit A and 17 of 54 trials (31%) for unit C. Field interferent testing showed false positive responses to most smokes, indicating that the instrument might give false CW detection responses during smoky emergency situations when there may not be actual CW agent vapor present.

The controlled laboratory environment tests with potential interferent substance vapors showed false positive responses to 1% saturation concentrations for 5 of 12 interferents tested, as well as false responses to 0.1% saturation concentrations to Windex and Spray 9 cleaner . This is not an uncommon occurrence with interferent testing of vapor detectors. The ability to detect HD and GB in the presence of a potentially interfering vapor, when the vapor itself does not cause a false alarm, was demonstrated. Only 1% vinegar vapor interference prevented detection of HD, i.e. a false negative. HD detection response resumed when the vinegar vapor was lowered to the 0.1% level.

The IMS2000™ offers fast and sensitive detection warning for the presence of the CW agents tested, however the false responses to the interferents tested is a concern.

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Appendix
Glossary

DP	Domestic preparedness
AEL	Airborne exposure limit
AFFF	Aqueous film forming foam, used for fire fighting
AR	Army regulation
ATT	Applied Test Team
CASARM	Chemical agent standard analytical reference material
CW	Chemical Warfare
DOD	Department of Defense
FPD	Flame photometric detector
GA	Tabun, a CW agent
GB	Sarin, a CW agent
GF	A CW agent
GS	An IMS2000™ code for CW (nerve) agent simulant
HAZMAT	Hazardous materials
HD	Mustard, a CW agent
HTH slurry	Calcium hypochlorite solution, a chlorinating decontaminant for CW agents
IDLH	Immediate danger to life or health
IPE	Individual protective equipment
JP8	Jet propulsion fuel
JSOR	Joint service operational requirements for detectors
L	Lewisite, a CW agent
L/min	Liters per minute
LCD	Liquid crystal display
MINICAMS®	Trade name for a chemical agent detector, the "Miniature Continuous Air Monitoring System."
MDL	Minimum detectable level
mg/m^3	Milligrams per cubic meter,
mL/min	Milliliters per minute
NBC	Nuclear, biological and chemical
PCT	Pre-concentrator tube
ppm	Parts per million
RH	Relative humidity
Sarin	A CW agent, also called GB.
SBCCOM	U.S. Army Soldier and Biological Chemical Command
SCBA	Self-contained breathing apparatus
TWA	Time-weighted average
VX	A CW agent